NRL-Contract Monthly Report for April 94

LOW VOLTAGE ELECTRON BEAM LITHOGRAPHY

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The contract has three parts covering aspects of high precision electron beam lithography. (1) Comprehensive computer modeling of the electron beam tool. (2) Experimental determination of the properties of sources, columns, and targets, and (3) The use of silicon single crystals as straightness and orthogonality standards using orientation dependent etching techniques.

Tasks 1-4. Comprehensive modeling of the electron beam tool.

In the previous reporting periods progress in the calculation of an empirical elastic scattering cross section for electron/atom scattering was reported.

Preparation of a publication of the cross section has been completed and is to be published in the Journal of Applied Physics in August 94. The title is:

"Empirical forms for the Electron/Atom Elastic Scattering Cross Section from 0.1-30 keV"

R.Browning T.Z.Li, B.Chui, Jun Ye, R.F.W.Pease,
C Czyzewshi, and D.C.Joy.

Preparation for the NIST 2day workshop "Electron Beam/Specimen Interaction Modeling for Metrology and Microanalysis in the Scanning Electron Microscope" in Charlston SC from May 17-19th has been started. R.Browning is an invited speaker at this workshop A photostat of the abstract is attached.

Electron/Atom Elastic Scattering Cross Sections from 0.1–30 keV

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Monte Carlo simulations of electron scattering in a target normally use one of two elastic cross sections, either the screened Rutherford cross section or tabulated partial wave expansions of the Mott cross section. The screened Rutherford cross section gives acceptable results for high energies and low atomic numbers, but Mott cross sections are required for low to medium incident energies (0.1–30keV) and high atomic number targets. However, computations tend to be slow using tabulated data due to the need to interpolate between data points. Empirical equations for the total and differential electron/atom elastic scattering cross sections have been found that can be substituted for tabulated Mott cross sections in predicting backscattering coefficients.

The total elastic Mott scattering cross section[1] is fitted by similar form to the screened Rutherford cross section but contains three terms in energy in the denominator. The empirical total elastic scattering cross section is valid for atomic numbers up to 92 and for energies from 100eV to 30keV:

$$\sigma_T = \frac{3.0\times10^{-18}Z^{1.7}}{(E+0.005Z^{1.7}E^{0.5}+0.0007Z^2/E^{0.5})} \quad (1)$$

The fit to the differential Mott cross sections is decomposed into two parts, one part being of the same mathematical form as the screened Rutherford cross section (σ_R), and the second part being an isotropic distribution (σ_I). The screened Rutherford part of the differential scattering cross section is first fitted to the half angle of the Mott cross sections. This fit of the differential screened Rutherford is in turn reduced to a fit of the screening parameter alone over energy and atomic number. In marked contrast to the screened Rutherford cross section, the tabulated Mott cross sections show only a small overall downward trend in half angle with increasing atomic number(Z). Implying an average Rutherford screening parameter for all Z, with E the electron energy, of:

$$\alpha = 7.0\times10^{-3}/E \quad (2)$$

The ratio of the total cross sections (σ_R/σ_I) between the screened Rutherford part of the differential scattering cross section and the isotropic part of the distribution is fitted to the backscattering coefficients calculated directly from tabulated Mott cross sections. The ratio of Rutherford to isotropic cross sections is:

$$\frac{\sigma_{Rutherford}}{\sigma_{Isotropic}} = \frac{300E^{1-Z/2000}}{Z} + \frac{Z^3}{3\times10^5 E} \quad (3)$$

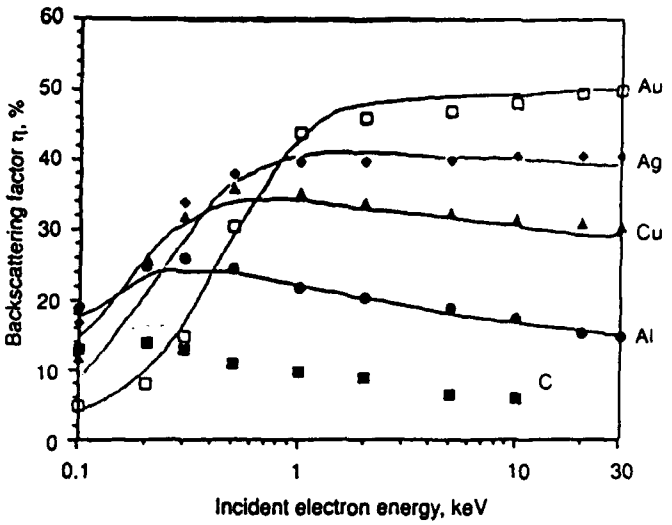

FIG. 1 Comparison of calculated backscattering factors using Eqs. 1–3, 7 (solid lines) and the calculations of Czyzewski *et al.*[1] using tabulated Mott cross sections (symbols).

Figure 1 shows a comparison of the calculated backscattering factors using the present empirical fit (solid lines) with those calculated using Mott cross sections.[1] The fit for Al, Cu, and Au is good over the entire energy range. The fit for Ag is moderate and the fit for C is high. However, most deviations are similar to differences because of the use of different atomic models in the Mott cross sections and are acceptable. There are two major reasons why the simple monotonic Eqs. 1–3 work well. First, the scattering of the electrons in a solid is a multiple scattering process. Thus, many of the complex quantum interference effects are averaged out. Second, the elastic backscattering is monotonic with atomic number. These two factors serve to smooth out the effects of the complex multidimensional cross sectional surface that is being fitted over Z, E, and θ.

Reference

1. Czyzewski Z, O'Neill MacCallum D, Romig A, Joy DC. *J Appl Phys* 68, 3066 (1990)

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